SILICA

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Four silica categories are covered in this report—industrial sand and gravel, quartz crystals (a form of crystalline silica), special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes tripoli and other fine-grained, porous silica materials, such as rottenstone, that have similar properties and end uses. Certain silica and silicate materials, such as diatomite and pumice, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook.

Industrial Sand and Gravel

Total industrial sand and gravel production decreased slightly to 27.3 million metric tons (Mt) in 2002 compared with that of 2001 (table 1). Compared with those of 2001, industrial sand production decreased by 3.7%, and gravel production increased by about 34%.

Industrial sand and gravel, often called “silica,” “silica sand,” and “quartz sand,” includes sands and gravels with high silicon dioxide (SiO_2) content. These sands and gravels are used, for example, in glassmaking and for abrasive, foundry, and hydraulic fracturing (frac) applications. The specifications for each use vary, but silica resources for most uses are abundant. In almost all cases, silica-mining uses open pit or dredging methods with standard mining equipment. Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact.

The production decrease for silica sand was minimal after several years of increasing demand for many uses, which included ceramics, chemicals, fillers (ground and whole-grain), filtration, flat and specialty glass, hydraulic fracturing, recreational, and roofing granules. The demand for silica gravel, which was used for filtration and nonmetallurgical flux, experienced a significant increase. Decreases in the total production of silica can be attributed in part to overall flat demand and the decline of growth in the economy in 2002. Additionally, the overall value declined slightly.

Legislation and Government Programs.—One of the most important issues to have had an impact on the industrial minerals industry in recent times has been the question of crystalline silica and its effect on human health. Central to the ongoing and often heated debate has been the understanding of the regulations and implementation of the measurements and actions taken with regard to exposure to crystalline silica and, most significantly, appreciation of its impact on the future of many industries (Industrial Minerals, 1998a). Many of the aforementioned issues, which include levels of exposure and the relationship between respirable silica and lung cancer, remained unresolved by consumers, miners, and regulatory agencies (Aggman, 2002).

Production.—Domestic production data for industrial sand and gravel were derived by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 67 producers with 157 operations known to produce industrial sand and gravel. Of the 157 surveyed operations, 143 (91%) were active, and 14 were idle. The USGS received responses from 114 operations, and their combined production represented about 82% of the U.S. total. Production for the 43 nonrespondents was estimated, primarily on the basis of previously reported information supplemented with man-hour reports from the U.S. Department of Labor’s Mine Safety and Health Administration and information from State agencies.

The Midwest (East North Central and West North Central divisions) continued to lead the Nation with about 41% of the 27.3 Mt of industrial sand and gravel produced in the United States, followed by the South (South Atlantic, East South Central, and West South Central divisions) with 39% and the West (Pacific and Mountain divisions) with 13% (table 2, figure 1).

The leading producing States, in descending order, were Illinois, Michigan, California, Wisconsin, Texas, New Jersey, Oklahoma, and North Carolina (table 3). Their combined production represented about 59% of the national total. Of the 36 States that produced silica in 2002, 16 had increased production, 16 had decreased production, and 4 stayed about even compared with 2001. South Carolina, Minnesota, Illinois, and Pennsylvania reported the largest increases, and Michigan, Texas, New Jersey, and Ohio reported the largest decreases.

About 82% of the total industrial sand and gravel was produced by 50 operations, each with production of more than 200,000 metric tons per year (t/yr) (tables 4, 5). The 10 leading producers of industrial sand and gravel, in descending order, were Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Nugent Sand Co. Inc., Little Six Corp., Simplot Industries Inc., Owens-Illinois, Inc., and Huey Stockstill, Inc. Their combined production from 76 operations represented 76% of the U.S. total.

Consumption.—Sand and gravel production reported by producers to the USGS was material sold to their customers or used by the companies. Stockpiled material is not reported until consumed or sold. Of the 27.3 Mt of industrial sand and gravel sold or used, about 38% was consumed as glassmaking sand, and 20%, as foundry sand (table 6). Building products, which is a broad category that includes nonskid flooring, paints, putty, and stucco, consumed about 8.7% of industrial sand and gravel production. Other important uses were frac sand (5.4%) and abrasive sand (4.7%).

Minable resources of industrial sand and gravel occur throughout the United States, and successful mining companies are located near markets, which have traditionally been in the Eastern United States. In some cases, consuming industries are specifically located near a silica resource. Because of the abundance of silica deposits, locating near a silica resource has not always been a priority, although it certainly has been a consideration. The auto industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been widely produced in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2002, more than 83% of foundry sand was produced in the Midwest.

Conversely, the glass industry located plants where it could minimize the shipping distance of finished glass products (for example, container, flat). Hence, glass plants were more evenly distributed. In 2002, 42% of glass sand was produced in the South; 31%, in the Midwest; 17%, in the West; and 10%, in the Northeast. To varying degrees, all silica production and sales are similarly influenced by the location of the consuming industries.

Some improvements in data collection affected the distribution by market segment for glass sand. Some sand consumption formerly attributed to container and fiberglass production has been reclassified as flat and specialty glass segments. Although the increasing or decreasing trends in each market accurately reflect the growth in the various glass segments, the actual increase or decrease is, therefore, likely not as large as the statistics portray.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was about 38%. This percentage increased slightly compared with that of 2001. In 2002, sales to container glass manufacturers increased slightly compared with those of 2001. The amount of sand consumed for fiberglass production increased by 24% compared with that of 2001.

In 2002, sales of sand for flat glass production decreased by about 5% compared with those of 2001. In the Midwest, consumption for flat glass decreased by 33%, and in the South, the decrease was slight.

Specialty glass consists of many segments, but the largest portion comprises laboratory and lighting glass (for example, incandescent light bulbs, fluorescent light bulbs). Specialty laboratory glass also makes up part of the components used in many segments of the electronics industry, including in the production of optical fiber and semiconductors.

The U.S. fiberglass industry consists of four major insulation manufacturers and six major textile producers. Continuous glass fiber specifications are very strict. Batch grain-size control is very important, so ground silica (ultrafine powder) is used. Iron, potassium, and sodium oxide content is tightly controlled. The raw mix is fused at 1,600° C and then passed through platinum bushings at 1,300° C. Various mineral wools are fabricated by using basalt and diabase (rock wool), blast furnace slag (slag wool), or glass (glass wool) (Industrial Minerals, 1998c).

Silica is used in ceramics in ground and whole-grain forms. Generally, 22% to 32% of the ceramic body of sanitaryware (for example, sinks, toilets, and urinals) composes whole-grain silica. Ground silica is used to decrease viscosity and the expansion coefficient of ceramic glazes and ceramic materials in applications. A typical glaze composition consists of about 25% quartz or silica. In 2002, about 323,000 metric tons (t) of ground silica was used in ceramic production.

Advanced ceramics, such as silicon nitride and silicon carbide, represent a growing market for silica and silica-based chemicals. Silicon carbide is manufactured by cooking silica sand or crushed quartz and oil coke at 2,400° C in an electric furnace for several days; sawdust or rice husks are added to increase porosity. Because of the anthropomorphic thermal conductivity and expansion coefficient of silicon carbide, it is especially useful in the refractory industry (Industrial Minerals, 1998b). Applications for silicon carbide include composite bearings used in a variety of pumps or wear parts, such as dynamic pressure, seal rings, shafts, slide bearings. The global market for silicon nitride, which is based on powder use, has been estimated to be 300,000 t/yr. Primary markets for hybrid bearings, which are based on these materials, have been aerospace components, dental drills, vacuum systems, and gyroscopes and machine tool spindles. Other markets for silicon nitride included cutting tools and engine components (Ceramic Industry, 1998).

Silica also is used in plastics as an extender, filler, and reinforcer. Whole-grain and ground silica are used in filler-type applications. Ground silica is used to thicken liquid systems, to avoid plateout in polyvinyl chloride, as a thixotropic and flatting agent, and in many other filler applications. Silica also is used in paint because it offers acid, scrubbing, and wear resistance. Consumption in 2002 of whole-grain filler was about 2.1 Mt, and ground silica for filler was 285,000 t.

Synthetic cristobalite, a high-temperature silica mineral, is made by heating quartz to above 1,470° C. It consists of small octahedral crystals, which aggregate into rounded particles. The crystal structure is more open than quartz, resulting in lower specific gravity. The major market for cristobalite is in the solid mold industry, but it is also used in ceramics, grinding products, reflective coatings, refractories, and paint used on road surfaces (Paint and Coatings Industry, 1997).

Sodium silicate, produced primarily by reacting sand and soda ash in a furnace, is one of the traditional chemicals made with silica sand. One of the forces that drives the increased demand for sodium silicate is the zeolite industry, which uses sodium silicate in synthetic zeolite production.

Potassium silicate is produced in a process similar to that for sodium silicate but uses potassium carbonate or potassium hydroxide. Potassium silicate is more expensive than sodium silicate and is used primarily in welding rods as a flux.

Specialty silicas are produced primarily by means of chemical and thermal processing of natural silica or silicon metal or as a byproduct of other mineral or chemical processing. Although the USGS does not specifically collect information on specialty silicas, consumption does affect natural silica sales. Specialty silicas and silanes (silica chemicals) include colloidal silicas, pyrogenic (fumed) silica, fused silica and quartz, organofunctional silanes, precipitated silica, silica gels, silicones, and ultra-high-purity silica. These silicas are used in a variety of industries and products, which includes abrasives, adhesives, beverages, catalysts, coatings, electronics, encapsulants, food, health care, optics, paper and packaging, plastics, refractories, rubber, sealants, specialty coatings, textiles, thermoplastics, wafer polishing, and water treatment.

Fumed silica forms tridimensional polymers used as thixotropic agents in silicons and silanes and is widely used as a coating agent for filler-grade calcium carbonate (Industrial Minerals, 1998c). In table 6, industrial sand and gravel that would find its way into these specialty silicas is most likely reported by the producers in the categories “Chemicals,” “Silicon metal,” and possibly “Glassmaking, specialty.” In 2002, silica sales for chemical production were 877,000 t, which was an increase of about 19% compared with those of 2001. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by about 4% in 2002 compared with those of 2001. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys.

Optical fiber production involves a series of highly sophisticated manufacturing methods. For the optical fiber, a glass core with a high refractive index surrounded by glass with a lower refractive index is required. This problem has been solved by using several manufacturing methods, such as producing all the fiber with fused silica but doping its core with an element that increases the refractive index (Industrial Minerals, 1998b).

The high-purity fused silica used by the electronics industry is typically at least 99.95% SiO_2 and has a high electromagnetic radiation transparency, a very low expansion coefficient, and good insulation properties. Silica grain and powder products are mainly produced from fused silica, which is made from silica sands. Fused silica has characteristics similar to zircon and is often mixed with zircon to form casting shells (Industrial Minerals, 2002b).

Synthetic precipitated silica and silica gel are produced by reacting sodium silicate with hydrochloric acid. Precipitated silica has been used increasingly in tires, more so in Europe than in the United States. Through replacement of a proportion of carbon black with precipitated silica in the tread, the reinforcing action of the silica particles extends tire life (Industrial Minerals, 2000b). European consumers prefer the “green” tires made with precipitated silica, and it is used in 70% to 80% of tires for passenger cars in Europe (Industrial Minerals, 2000a). Although these tires reportedly produce greater gas mileage, higher costs to consumers and manufacturers account for their lack of popularity in the United States. Some new silicas, which aim to alleviate these problems, are being produced. If these problems are solved, then the “green” tire will probably become more popular in the United States. Precipitated silica is also used in battery separators and as a flatting agent in coatings, mainly high-solid, low-volatility organic compound coatings.

Transportation.—Of the total industrial sand and gravel produced, 64% was transported by truck from the plant to the site of first sale or use, up from 62% in 2001; 34% was transported by rail, down from 35% in 2001; and 2%, by waterway.

Prices.—Compared with the average value of 2001, the average value, free on board plant, of U.S. industrial sand and gravel increased slightly to $20.96 per metric ton in 2002 (table 6). The average unit values for industrial sand and industrial gravel were $21.36 per ton and $13.66 per ton, respectively. The average price for sand ranged from $11.67 per ton for metallurgical flux to $82.87 per ton for ground fillers. For gravel, prices ranged from $10.05 per ton for nonmetallurgical flux to $31.31 per ton for filtration. Producer prices reported to the USGS for silica commonly ranged from several dollars per ton to hundreds of dollars per ton, and occasionally prices exceeded the $1,000-per-ton level. Nationally, ground sand used as fillers for paint, putty, and rubber had the highest value ($82.87 per ton), followed by ground sand for foundry molding and core ($82.43 per ton), silica for swimming pool filters ($77.07 per ton), sand for well packing and cementing ($64.63 per ton), silica for municipal water filtration ($41.83 per ton), ground sand for fiberglass ($40.87 per ton), sand for hydraulic fracturing ($40.08 per ton), and abrasives for sawing and sanding ($36.86 per ton).

Industrial sand and gravel price changes were mixed; some markets remained level, others had small increases or decreases, and still others had large increases or decreases. Although the silica was essentially the same, this situation was possible because most markets were independent of each other, and price competition was influenced by availability, competition from other materials, health concerns, and regulations.

By geographic region, the average value of industrial sand and gravel was highest in the South ($23.09 per ton), followed by the West ($22.74 per ton), the Northeast ($21.85 per ton), and the Midwest ($18.20 per ton) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, the average value of glass sand varied from $26.12 per ton in the West to $16.16 per ton in the Midwest. Tighter supplies and higher production costs in the West and much greater competition in the Midwest caused the difference in the cost of sand and gravel in these two regions.

Destination of Shipments.—Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section) and to which State or other location the material was shipped for consumption. The States that received the most industrial sand and gravel were California (8.8%), Texas (7.3%), Illinois (6.7%), Ohio (5.3%), Pennsylvania (5%), and Indiana (4.6%). Producers reported sending at least 655,000 t of silica to Canada and 338,000 t to Mexico (table 7).

Because some producers did not provide this information, their data were estimated or assigned to the “Destination unknown” category. In 2002, 7.2% of industrial sand and gravel shipped by producers was assigned to that category.

Foreign Trade.—Based on U.S. Census Bureau data, exports of industrial sand and gravel in 2002 decreased by 8.4% compared with the amount exported in 2001, and the associated value decreased by 11% (table 8). Most of the decrease in exports was attributable to further sharp declines in shipments to Asia and Europe. Canada was the largest recipient of U.S. exports. Export distribution was as follows: 39% to Canada, 35% to Mexico, 12% to Japan, 4% to Europe, and the remainder to South America, the Middle East and Africa, and Oceania. The average price of exports decreased to $103 per ton in 2002 from $106 per ton in 2001. In 2002, export prices varied widely by region; exports of higher grade silica to Europe averaged about $585 per ton, and exports to the rest of the world averaged $81 per ton.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel rose to 250,000 t, which was a sharp increase of 45% compared with those of 2001 (table 9). Silica imports vary greatly from year to year but are rather insignificant in relation to total consumption. Mexico supplied 72% of the silica imports, which averaged $6.66 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was about $8.7 million, with an average of about $35 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 95 Mt. The United States was the leading producer followed by Germany, Austria, France, Spain, Australia, and the United Kingdom, in descending order. Most countries in the world had some production and consumption of industrial sand and gravel, which are essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption (table 12).

Outlook.—The forecast range of total U.S. consumption for industrial sand and gravel in 2003 is 26 to 28 Mt. Consumption is expected to be about 27 Mt. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecasts made by analysts and producers in the various markets.

Sales of glass sand are expected to vary from market to market. Growth that might come in some segments, such as flat and specialty glasses, will be offset by reductions in sales for container glass and possibly fiberglass. The trend towards a decreasing market share for container glass in the United States is expected to continue. Total demand for glass sand is expected to grow slowly, probably to the range of 10 to 12 Mt through 2003.

The demand for foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other “sands” usually suffer from a severe price disadvantage. Based on these factors, consumption of silica foundry sand in 2003 is expected to be 5.5 Mt, and the consumption range is expected to be 5 to 6 Mt.

Frac sand sales remained steady in 2002, compared with those of 2001. Based on this trend, demand for frac sand is expected to remain level during 2003. Demand for frac sand in 2003 is expected to be 1.5 Mt, with a range of 1.4 to 1.6 Mt.

The United States is the largest producer and consumer of silica sand and is self-sufficient in this mineral commodity. Most of it is produced at premier deposits in the Midwest and near major markets in the Eastern United States. A significant amount of silica sand is also produced in the West and the Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet more than 99% of demand well beyond 2002. Imports mostly from Canada and Mexico and higher valued material from China are expected to remain minor.

Because the unit price of silica sand is relatively low, except for a few end uses that require a high degree of processing, the location of a silica sand deposit in relation to the market is an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Several factors could affect supply and demand relations for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for foundry and glass sand. These substitutes, which are mainly ceramics and polymers, would likely increase the demand for ground silica, which is used as a filler in plastics; glass fibers, which are used in reinforced plastics; and silica (chemical, ground, or whole grain), which is used to manufacture ceramics. Increased efforts to reduce waste and to increase recycling also could hinder the demand for glass sand. Although developments could cause the demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the more specialized sands.

Health concerns about the use of silica as an abrasive and stricter legislative and regulatory measures concerning silica exposure could reduce the demand in many silica markets. The use of silica sand in the abrasive blast industry was being questioned as a health hazard as marketers of competing materials, which include garnet, olivine, and slags, encouraged the use of their “safer” abrasive media. Additionally, abrasive grade bauxite, which is the feedstock for brown fused alumina, is finding increasing use in abrasives and proppants (the latter application is used to hold fractures open in oil wells) (Industrial Minerals, 2002a).

Development of more efficient mining and processing methods is expected to continue. This will encourage the mining of lower grade silica sand deposits that are located closer to markets but are not presently mined. Such developments are expected to increase silica sand reserves.

Quartz Crystal

Electronic-grade quartz crystal is single-crystal silica with properties that make it uniquely useful in accurate filters, frequency controls, and timers in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, communications equipment, computers, consumer goods (for example, clocks, games, television receivers, and toys), and commercial and military navigational instruments. Such uses generate practically all the demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, which include some lasers.

Natural quartz crystal was used in most electronic and optical applications until 1971 when it was surpassed by cultured quartz crystal. The use of natural quartz crystal for carvings and other gemstone applications has continued (more information can be found in the Gemstones chapter of the USGS Minerals Yearbook).

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained wide use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of natural quartz crystal for a national stockpile began.

As of December 31, 2002, the National Defense Stockpile (NDS) contained about 105,557 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 to more than 10 kg. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

With cultured quartz crystal displacing natural quartz crystal in most applications, the Federal Government continues to assess its stockpile goals for the latter material. In the latest reports on the inventory of stockpile material, no quartz crystals were designated for disposal in 2002. No natural quartz crystal was sold in 2002. Previously, only individual crystals in the NDS inventory that weighed 10 kg or more and could be used as seed material were sold. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced output.

Quartz crystal is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" portion of the "Industrial Sand and Gravel" section of this review.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2002, the industry consisted of three cultured quartz crystal producers. One of the growers responded to the annual survey, and the other two were estimated based on previously reported figures. The following U.S. companies produced cultured quartz crystal during 2002: CTS Corp. of Carlisle, PA; Sawyer Research Products Inc. of Eastlake, OH; and Thermo Dynamics Corp. of Merriam, KS. P.R. Hoffman Material Processing Co. of Carlisle, PA, has the capacity to produce cultured quartz crystal but had no production in 2002. Sawyer Research Products and Thermo Dynamics produced crystal bars for domestic and foreign firms in the crystal-device-fabrication industry. CTS Corp. produced quartz crystal for internal consumption and domestic device fabricators.

The above-mentioned companies produced cultured quartz crystal using a hydrothermal process in large pressure vessels called autoclaves. Seed crystals are mounted on racks and suspended in the upper growth region of the vessel. Lascas, which is a high-purity natural quartz feedstock, is loaded in an open-mesh wire basket that is placed in the bottom of the autoclave. A solution of sodium hydroxide or sodium carbonate (the mineralizer) with such additives as lithium salts and deionized or distilled water is used to fill the vessel from 75% to 85% of its volume. The bottom one-half of the growing vessel is heated to temperatures averaging between 350° C and 400° C; the temperature of the top portion is maintained from 5° C to 50° C lower than that in the bottom one-half of the vessel depending upon the mineralizer used. At these temperatures, the solution expands and creates internal pressure between 700 and 2,100 kilograms per square centimeter. Under these conditions, the lascas dissolves to create a solution saturated with silica. Through convection, the saturated solution transports dissolved silica to the cooler upper one-half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top one-half of the autoclave. The process continues until the growing crystals reach their desired size. The process normally takes from 30 to 60 days for a 1-inch-thick bar and longer for other types of crystal; at least one producer has made runs of about 180 days. The cultured crystals can be custom grown with specific properties.

Processing quartz crystal for various end uses is the same whether natural or cultured seed crystal is used. Producers, however, must avoid seed crystals with defects that could be passed on to new generations of cultured crystal. Natural quartz crystal is preferred as seed material to ensure that genetic defects will not be repeated in the succeeding generations.

Once produced, cultured crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness, electrodes are then attached, and the crystals are mounted in suitable holders. The final assembly, which is called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—In 2002, the USGS collected domestic consumption data for quartz crystal through a survey of 26 U.S. operations that fabricate quartz crystal devices in 10 States. These operations represented virtually all the domestic consumption. Of the 26 operations, 15 responded to the survey. One company reported the closing of a processing plant. Consumption for nonrespondents was estimated based on reports from previous years.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications that require only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators also are used for many less demanding applications, such as providing timing signals for electronic circuits in automotive, consumer, and industrial products.

Cultured quartz is used almost exclusively by the crystal device industry because of the cost advantages. For resonator applications, raw cultured quartz must be cut into thin wafers oriented precisely in line with raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining applications of the natural electronic-grade material is in pressure transducers used in deep wells.

Quartz wafers must be cut thin for practical use at very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than by wafer thickness, have become more prevalent at these higher frequencies. These structures are called surface acoustic wave devices.

Most optical applications use quartz in the fused form as silica glass. Small quantities of cultured quartz crystal are used directly in optical applications. Quartz crystal also has uses that involve birefringent filters, Brewster windows and prisms, normally polarized laser beams, quartz retardation plates (especially quartz wave plates), and tuning elements in laser optics.

Prices.—The average value of as-grown cultured quartz was estimated to be about $52 per kilogram in 2002. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $251 per kilogram.

Foreign Trade.—The U.S. Department of Commerce (DOC), which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. Some lascas was imported from Brazil in 2002, according to some consumers.

World Review.—Cultured quartz crystal production is concentrated in China, Japan, Russia, and the United States; several companies produce crystal in each country. Other producing countries are Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, the Eastern European countries, and most nations of the Commonwealth of Independent States are unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—Because the demand for quartz crystal devices will probably continue to increase, quartz crystal production will probably remain strong well into the future. The trend towards importing quartz could have a negative affect on domestic quartz growers. Growth of the consumer electronics market (for example, automobiles, cellular telephones, electronic games, and personal computers), particularly in the United States, will continue to provide consumer outlets for domestic production. The growing global electronics market may require additional production capacity worldwide.

Special Silica Stone Products

Silica stone (another crystalline silica) products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains (information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook chapters).

Special silica stone is also affected by the regulation of crystalline silica as discussed in the “Legislation and Government Programs” part of the “Industrial Sand and Gravel” section of this chapter.

Production.—In response to a USGS production survey, six of nine domestic firms reported that they quarried certain silica materials and manufactured silica stone products during 2002. Data for the remaining producers were estimated. Arkansas accounted for most of the value and quantity of production reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones. Tumbling-grinding media were produced in Wisconsin (table 10).

The industry has produced and marketed four main grades of Arkansas whetstone in recent years. The grades range from the high-quality black hard Arkansas stone down to Washita stone. In general, the black hard Arkansas stone has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products is a combination of craft, household, industrial, and leisure uses. Major household uses include the sharpening of knives and other cutlery, lawn and garden tools, scissors, and shears. Leading industrial uses include the deburring of metal and plastic castings, the polishing of metal surfaces, and the sharpening and honing of cutting surfaces. Recreational uses include the sharpening of arrowheads, fishhooks, spear points, and sports knives. Craft applications include sharpening tools for engraving, jewelry making, and woodcarving. Silica stone files are also used in the manufacture, modification, and repair of firearms.

Prices.—The average value of crude material suitable for cutting into finished products was $321 per ton. The average value of stone products made from crude material was $9.69 per kilogram (table 1).

Foreign Trade.—In 2002, silica stone product exports had a value of about $7.3 million; that was up sharply from that of 2001. These exports were categorized as “hand sharpening or polishing stones” by the DOC. This category accounted for most of, if not all, the silica stone products exported in 2001.

In 2002, the value of imported silica stone products was at least $4.5 million; this was an increase of 15% compared with that of 2001. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2002. A portion of the finished products that were imported may have been made from crude novaculite produced in the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

Tripoli

Tripoli, broadly defined, comprises extremely fine grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers (µm), but particles as small as 0.1 to 0.2 µm are common. Commercial tripoli contains 98% to 99%

silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending upon the percentage of iron oxide.

Tripoli also is affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this review.

Production.—In 2002, five U.S. firms were known to produce and process tripoli. American Tripoli Co. produced crude material in Ottawa County, OK, and finished material in Newton County, MO. Keystone Filler and Manufacturing Co. in Northumberland County, PA, processed rottenstone, which is a decomposed fine-grained siliceous shale purchased from local suppliers. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Harbison-Walker Refractories Co. Inc. in Hot Springs County, AR, produced crude and finished tripoli that is consumed in the production of refractory bricks and shapes. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. All these firms responded to the USGS survey.

Consumption.—The 2002 USGS annual survey of producers indicates that sales of processed tripoli increased by 10% in quantity to 66,600 t with a value of about $16 million (table 1).

Tripoli has unique applications as an abrasive because of its hardness and its grain structure, which lacks distinct edges and corners. It is a mild abrasive, which makes it suitable for use in toothpaste and tooth-polishing compounds, industrial soaps, and metal- and jewelry-polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 30 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2002, about 24% of tripoli output was used as an abrasive. The remainder was used in brake friction products, as filler and extender in enamel, caulking compounds, linings, paint, plastic, refractories, rubber, and other products.

The primary use of tripoli (about 85%) is as a filler and extender in paints. In exterior latex paints, tripoli also aids in durability, flowability, leveling, and tint retention. In enamels, it makes application easier and improves sheen. The controlled grain and particle size of tripoli in paints improves dispersal and promotes a more uniform coating. Additionally, paints with tripoli resist chemical agents and wear better than those in which water-ground whitings and other softer or more reactive fillers are used.

Plastics, resins, and rubbers each account for about 5% of the tripoli used as a filler and extender. Tripoli is used extensively in plastics for electrical uses because of its dielectric characteristics and its effects on compression and flexibility properties. Its chemical resistance, resistance to salt spray, and weatherability also are important to its use in plastics. The physical properties of tripoli allow high frictional loading in most compounds, but its abrasiveness results in high wear in extruding nozzles and molds. The same properties that make tripoli useful as a filler and extender in plastic make it valuable to the rubber and resin industries.

Price.—The average reported unit value of all tripoli sold or used in the United States was $249 per ton in 2002. The average reported unit value of abrasive tripoli sold or used in the United States during 2002 was $210 per ton, and the average reported unit value of filler tripoli sold or used domestically was $273 per ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

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TABLE 1
SALIENT U.S. SILICA STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

		1998	1999	2000	2001	2002
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		26,400	26,900	26,800	26,900	25,900
Gravel		1,790	1,940	1,660	1,060	1,420
Total		28,200	28,900	28,400	27,900	27,300
Value:						
Sand		491,000	510,000	532,000	559,000	554,000
Gravel		22,200	28,400	24,400	17,600	19,400
Total		513,000	538,000	556,000	576,000	573,000
Exports:						
Quantity		2,400	1,670	1,660	1,540	1,410
Value		148,000	133,000	179,000	163,000	145,000
Imports for consumption:						
Quantity		44	211	247	172	250
Value		2,750	5,590	11,800	11,000	8,650
Processed tripoli:[3]						
Quantity	metric tons	79,600	84,900	72,000	60,500	66,600
Value		16,900	20,200	15,900 e	15,000	16,600
Special silica stone:						
Crude production:						
Quantity	metric tons	649	697	553	705	748
Value		184	183	158	234	240
Sold or used:						
Quantity	metric tons	438	475	312	393	386
Value		3,440	3,060	4,610	4,040	3,740
Electronic and optical-grade quartz crystals, production:						
Mine	metric tons	--	--	--	--	--
Cultured	do.	185	192	189	W	W

[e]Estimated. W Withheld to avoid disclosing company proprietary data. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes Puerto Rico.
[3]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC REGION1

	2001				2002			
Geographic region	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	138	(2)	W	W	157	1	W	W
Middle Atlantic	2,160	8	$49,600	9	2,050	7	$48,100	8
Midwest:								
East North Central	9,960	36	170,000	29	9,540	35	167,000	29
West North Central	1,480	5	31,200	5	1,570	6	35,700	6
South:								
South Atlantic	4,090	15	86,300	15	4,240	16	88,100	15
East South Central	2,240	8	43,200	8	2,220	8	45,700	8
West South Central	4,330	16	118,000	20	4,110	15	110,000	19
West:								
Mountain	1,380	5	24,100	4	1,360	5	23,600	4
Pacific	2,140	8	54,600	9	2,090	8	55,000	10
Total	27,900	100	576,000	100	27,300	100	573,000	100

W Withheld to avoid disclosing company proprietary data; included with "Middle Atlantic."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than 1/2 unit.

TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	2001		2002	
	Quantity	Value	Quantity	Value
Alabama	743	9,420	722	8,990
Arizona	W	W	W	W
Arkansas	W	W	W	W
California	1,840	47,700	1,800	48,000
Colorado	W	W	61	W
Florida	598	7,520	645	8,640
Georgia	W	W	606	12,200
Idaho	W	W	W	W
Illinois	4,460	72,100	4,510	72,800
Indiana	W	W	W	W
Iowa	35	1,590	W	W
Kansas	W	W	W	W
Louisiana	637	11,900	672	13,100
Maryland	W	W	W	W
Michigan	2,530	30,000	2,210	31,000
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Nebraska	W	W	W	W
Nevada	609	W	615	11,000
New Jersey	1,580	34,800	1,420	32,700
New Mexico	W	W	W	W
New York	W	W	W	W
North Carolina	1,300	26,000	1,320	25,600
North Dakota	W	W	W	W
Ohio	1,120	30,700	1,000	28,900
Oklahoma	1,360	28,200	1,320	28,400
Pennsylvania	W	W	W	W
Rhode Island	138	W	157	W
South Carolina	694	15,900	831	16,400
Tennessee	W	22,900	1,070	25,700
Texas	1,850	70,000	1,670	62,200
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,710	W	1,740	32,700
Other	6,720	167,000	4,960	115,000
Total	27,900	576,000	27,300	573,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE
UNITED STATES IN 2002, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	18	14	207	1
25,000 to 49,999	18	15	619	2
50,000 to 99,999	22	17	1,440	5
100,000 to 199,999	19	15	2,570	10
200,000 to 299,999	14	12	3,040	12
300,000 to 399,999	6	5	1,990	7
400,000 to 499,999	11	8	4,510	16
500,000 to 599,999	7	5	3,480	12
600,000 to 699,999	4	3	2,340	9
700,000 and more	8	6	7,150	26
Total	127	100	27,300	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS
IN THE UNITED STATES IN 2002, BY GEOGRAPHIC REGION

	Mining operations on land					
Geographic region	Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	1	--	--	--	--	1
Middle Atlantic	7	--	--	--	5	12
Midwest:						
East North Central	24	--	--	--	6	30
West North Central	4	--	--	--	6	10
South:						
South Atlantic	18	--	--	2	6	26
East South Central	8	--	--	--	3	11
West South Central	11	--	--	--	10	21
West:						
Mountain	6	--	--	--	--	6
Pacific	9	--	--	--	1	10
Total	88	--	--	--	37	127

-- Zero.

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2002, BY MAJOR END USE[1]

Major use	Northeast Quantity (thousand metric tons)	Northeast Value (thousands)	Northeast Value[2] (dollars per ton)	Midwest Quantity (thousand metric tons)	Midwest Value (thousands)	Midwest Value[2] (dollars per ton)	South Quantity (thousand metric tons)	South Value (thousands)	South Value[2] (dollars per ton)
Sand:									
Glassmaking:									
Containers	564	$10,800	$19.22	1,450	$15,900	$10.97	1,570	$25,800	$16.38
Flat, plate and window	W	W	18.03	967	11,700	12.07	1,720	29,200	16.95
Specialty	W	W	24.91	302	5,430	17.99	275	6,120	22.27
Fiberglass, unground	W	W	19.21	356	4,520	12.69	449	7,330	16.33
Fiberglass, ground	--	--	--	W	W	27.10	400	18,500	46.29
Foundry:									
Molding and core, unground	248	4,990	20.10	4,550	65,100	14.31	579	10,100	17.41
Molding and core, ground	--	--	--	W	W	74.83	W	W	128.00
Refractory	(4)	2	17.82	W	W	23.44	W	W	47.43
Metallurgical:									
Silicon carbide	--	--	--	47	926	19.70	--	--	--
Flux for metal smelting	--	--	--	--	--	--	W	W	51.50
Abrasives:									
Blasting	21	784	37.33	172	5,060	29.40	943	28,500	30.18
Scouring cleansers, ground	(4)	(4)	63.80	10	293	29.30	(4)	11	30.14
Sawing and sanding	W	W	23.50	--	--	--	--	--	--
Chemicals, ground and unground	W	W	20.84	306	4,200	13.72	465	12,400	26.74
Fillers, ground, rubber, paints, putty, etc.	--	--	--	103	8,950	86.92	178	14,600	81.74
Whole grain fillers/building products	216	6,790	31.44	552	13,200	23.96	912	17,000	18.69
Ceramic, ground, pottery, brick, tile, etc.	(3)	14	65.87	W	W	72.17	286	6,500	22.72
Filtration:									
Water, municipal, county, local	32	1,620	50.47	68	3,080	45.24	169	5,730	33.93
Swimming pool, other	14	906	64.71	18	1,430	79.44	41	3,650	89.12
Petroleum industry:									
Hydraulic fracturing	W	W	71.93	1,050	34,900	33.14	402	23,400	58.22
Well packing and cementing	13	609	46.85	1	83	83.00	80	5,470	68.34
Recreational:									
Golf course, greens and traps	123	2,190	17.80	208	4,230	20.31	321	3,580	11.14
Baseball, volleyball, play sand, beaches	59	1,170	19.78	76	2,400	31.62	64	561	8.77
Traction, engine	W	W	21.73	71	999	14.07	44	612	13.91
Roofing granules and fillers	40	975	24.38	(4)	18	448.97	201	3,330	16.58
Other, ground silica	W	W	20.84	288	11,200	38.89	28	193	2.41
Other, whole grain	835	16,500	19.80	393	7,340	18.42	770	11,300	14.34
Total or average	2,170	47,400	21.90	11,000	201,000	18.28	9,900	234,000	23.62
Gravel:									
Silicon, ferrosilicon	--	--	--	W	W	18.20	W	W	14.69
Filtration	W	W	52.00	W	W	52.11	W	W	24.24
Nonmetallurgical flux	--	--	--	W	W	18.00	--	--	--
Other uses, specified	38	698	18.37	115	1,250	10.85	673	10,300	15.26
Total or average	38	698	18.37	115	1,250	10.85	673	10,300	15.26
Grand total or average	2,200	48,100	21.85	11,100	202,000	18.20	10,600	244,000	23.09

See footnotes at end of table.

TABLE 6--Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2002, BY MAJOR END USE[1]

Major use	West Quantity (thousand metric tons)	West Value (thousands)	West Value[2] (dollars per ton)	U.S. total Quantity (thousand metric tons)	U.S. total Value (thousands)	U.S. total Value[2] (dollars per ton)
Sand:						
Glassmaking:						
Containers	1,030	$21,500	$20.91	4,610	$74,000	$16.03
Flat, plate and window	W	W	17.75	3,550	56,200	15.83
Specialty	W	W	31.25	881	19,200	21.80
Fiberglass, unground	W	W	24.69	867	13,200	15.22
Fiberglass, ground	W	W	36.00	558	22,800	40.87
Foundry:						
Molding and core, unground	78	1,460	18.71	5,460	81,700	14.96
Molding and core, ground	--	--	--	(3)	(3)	82.43
Refractory	--	--	--	23	708	30.78
Metallurgical:						
Silicon carbide	--	--	--	47	926	19.70
Flux for metal smelting	W	W	6.75	18	210	11.67
Abrasives:						
Blasting	136	5,330	39.17	1,270	39,600	31.18
Scouring cleansers, ground	--	--	--	10	304	30.40
Sawing and sanding	W	W	39.08	(3)	(3)	36.86
Chemicals, ground and unground	W	W	47.83	877	19,200	21.86
Fillers, ground, rubber, paints, putty, etc.	W	W	38.00	285	23,600	82.87
Whole grain fillers/building products	424	14,800	35.00	2,100	51,900	24.67
Ceramic, ground, pottery, brick, tile, etc.	W	W	20.62	323	8,510	26.35
Filtration:						
Water, municipal, county, local	103	5,130	49.84	372	15,600	41.83
Swimming pool, other	12	484	40.33	84	6,470	77.07
Petroleum industry:						
Hydraulic fracturing	W	W	40.91	1,480	59,200	40.08
Well packing and cementing	5	239	47.80	99	5,400	64.63
Recreational:						
Golf course, greens and traps	224	5,420	24.20	875	15,400	17.61
Baseball, volleyball, play sand, beaches	14	266	19.00	214	4,400	20.55
Traction, engine	W	W	27.33	157	2,580	16.40
Roofing granules and fillers	--	--	--	242	4,330	17.88
Other, ground silica	14	266	19.00	XX	XX	XX
Other, whole grain	825	16,500	20.01	XX	XX	XX
Total or average	2,860	71,400	24.95	25,900	554,000	21.36
Gravel:						
Silicon, ferrosilicon	--	--	--	607	8,920	14.69
Filtration	W	W	31.88	W	W	31.31
Nonmetallurgical flux	W	W	95.24	W	W	10.05
Other uses, specified	593	7,150	12.06	XX	XX	XX
Total or average	593	7,150	12.06	1,420	19,400	13.66
Grand total or average	3,450	78,500	22.74	27,300	573,000	20.96

W Withheld to avoid disclosing company proprietary data; for sand, included with "Other, ground silica" or "Other, whole grain;" for gravel, included with "Other uses, specified." XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits, except for values per metric ton; may not add to totals shown.

[2]Calculated by using unrounded data.

[3]Included with "Total or average."

[4]Less than 1/2 unit.

TABLE 7
INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION[1]

(Thousand metric tons)

Destination	2001	2002	Destination	2001	2002
States:			States--Continued:		
Alabama	784	798	New Jersey	899	798
Alaska	--	(2)	New Mexico	128	105
Arizona	307	298	New York	372	437
Arkansas	57	62	North Carolina	1,040	1,040
California	2,550	2,420	North Dakota	20	20
Colorado	170	233	Ohio	1,420	1,460
Connecticut	52	54	Oklahoma	649	546
Delaware	18	10	Oregon	62	67
District of Columbia	2	(2)	Pennsylvania	1,260	1,380
Florida	677	741	Rhode Island	66	59
Georgia	851	822	South Carolina	208	472
Hawaii	--	(2)	South Dakota	5	11
Idaho	432	423	Tennessee	978	945
Illinois	1,930	1,840	Texas	1,980	2,000
Indiana	1,070	1,260	Utah	38	46
Iowa	199	246	Vermont	3	3
Kansas	435	437	Virginia	305	318
Kentucky	318	281	Washington	202	222
Louisiana	833	745	West Virginia	283	162
Maine	(2)	(2)	Wisconsin	1,040	1,090
Maryland	122	105	Wyoming	142	133
Massachusetts	64	60	Countries:		
Michigan	1,200	1,220	Canada	874	655
Minnesota	319	320	Mexico	286	338
Mississippi	268	194	Other foreign countries	40	56
Missouri	466	319	Other:		
Montana	11	10	Puerto Rico	(2)	(2)
Nebraska	29	55	U.S. possessions and territories	3	(2)
Nevada	47	52	Destination unknown	2,400	1,960
New Hampshire	6	9	Total	27,900	27,300

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than 1/2 unit.

TABLE 8

U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2001		2002	
Country	Quantity	F.a.s. value[2]	Quantity	F.a.s. value[2]
North America:				
Bahamas, The	1	134	1	136
Canada	305	32,000	556	30,100
Mexico	650	22,100	490	16,100
Panama	18	427	18	332
Other	3	611	26	1,170
Total	977	55,300	1,090	47,800
South America:				
Argentina	18	2,740	20	2,640
Brazil	2	1,190	2	1,500
Colombia	(3)	82	1	134
Peru	3	128	(3)	102
Venezuela	3	1,190	(3)	265
Other	1	327	6	563
Total	27	5,660	29	5,200
Europe:				
Belgium	3	1,870	3	1,510
France	64	11,700	2	1,310
Germany	20	17,800	12	13,300
Italy	4	2,420	(3)	1,100
Netherlands	31	9,420	28	10,600
Switzerland	1	708	1	994
United Kingdom	23	4,660	11	4,520
Other	3	1,980	3	1,810
Total	149	50,600	60	35,100
Asia:				
China	6	3,760	10	5,290
Indonesia	2	836	2	970
Japan	325	19,200	166	19,200
Korea, Republic of	13	5,110	5	2,750
Malaysia	2	1,900	5	3,920
Singapore	17	6,060	6	8,240
Taiwan	11	6,870	10	5,390
Thailand	3	693	4	956
Other	1	655	1	527
Total	380	45,000	209	47,200
Middle East and Africa:				
Algeria	1	563	(3)	274
Oman	(3)	210	6	4,650
Saudi Arabia	1	610	2	1,690
South Africa	(3)	71	5	115
Other	(3)	201 r	2	419
Total	2	1,660	15	7,150
Oceania:				
Australia	9	4,750	5	1,920
Other	(3)	125	(3)	106
Total	9	4,870	5	2,020
Grand total	1,540	163,000	1,410	145,000

[r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.

[3]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2001 Quantity	2001 C.i.f. value[2]	2002 Quantity	2002 C.i.f. value[2]
Australia	3	1,300	4	876
Canada	149	2,510	58	2,290
Chile	4	744	5	991
China	5	5,450	3	2,590
Germany	(3)	192	(3)	124
Japan	(3)	100	(3)	139
Mexico	(3)	4	180	1,200
Trinidad and Tobago	9	207	--	--
Other	2	508	(3)	439
Total	172	11,000	250	8,650

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[3]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 10
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 2002

Company and location	Type of operation	Product
B&C Abrasives, Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Blue Mountain Whetstone Co., Hot Springs, AR	do.	Do.
Dan's Whetstone Co., Inc., Hot Springs, AR	Stone cutting and finishing	Do.
Do.	Quarry	Crude novaculite.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Kraemer Co., The, Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Norton Company Oilstones:		
Hot Springs, AR	do.	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Smith Abrasives, Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Taylor Made Crafts Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Pearcy, AR	Quarry	Crude novaculite.

TABLE 11

SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS[1]

		1998	1999	2000	2001	2002
Production:						
Mine	metric tons	--	--	--	--	--
Cultured[e]	do.	185	192	189	W	W
Exports, cultured:[2]						
Quantity	do.	63	90	74	39 [r]	53
Value	thousands	24,300	25,400	22,800	10,600	11,000
Imports, cultured:[2]						
Quantity	metric tons	47	26	31	14	10
Value	thousands	12,200	11,000	14,300	8,390	2,100
Consumption, apparent[e]		169	128	146	W	W

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Excludes mounted piezoelectric crystals.

TABLE 12
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	1998	1999	2000	2001	2002[e]
Argentina	462	263	280 [e]	496 [r]	181 [4]
Australia[e]	2,500	2,500	4,266 [4, 5]	4,500 [5]	4,500
Austria	6,329	6,857	6,800 [e]	6,800 [e]	6,800
Belgium[e]	1,800	1,800	1,800	1,800	1,800
Bosnia and Herzegovina[e]	50	50	50	50	50
Brazil, silex[e]	1,600	1,600	1,600	1,600	1,600
Bulgaria[e]	893 [4]	900	900	900	900
Cameroon	15 [r, e]	16 [r]	-- [r]	-- [r]	--
Canada, quartz	1,905	1,702	1,946	1,613 [r]	1,556 [p]
Chile[e]	300	300	300	300	300
Croatia	112	99	96	95 [e]	95
Cuba	95	91	52 [r]	50 [r, e]	50
Czech Republic	827	980	985	950 [e]	900
Denmark, sales[e]	43	43	43	50	60
Ecuador	40	22	28	22 [r]	22
Egypt[e, 4]	574 [4]	600	600	600	600
Eritrea	--	10	--	10 [e]	10
Estonia	20	16	34	25 [r, e]	24
Ethiopia	7 [e]	6	6	6 [e]	6
Finland[e]	30	73 [4]	73 [r]	148 [r]	150
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia	270	173	170	170 [e]	170
Germany[e]	10,000 [4]	10,000	8,500	8,500	8,500
Greece[e]	90 [4]	90	90	90	90
Guatemala	125 [r]	116 [r]	173 [r]	170 [r, e]	170
Hungary	241	490	500	500 [e]	500
Iceland[e]	4	4	4	4	4
India[e]	1,265 [4]	1,300	1,350	1,400	1,400
Indonesia	145	120 [6]	124 [e, 6]	124 [e, 6]	124 [6]
Iran[e, 7]	1,000	1,000	1,000	1,700 [r]	1,700
Ireland[e]	5	5	5	5	5
Israel	257	320	300	306 [e]	330
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	6	9	7	8 [r]	8
Japan	3,049	2,764	2,746	2,537 [r]	2,150
Jordan	NA	52	47	49 [e]	53
Kenya[e]	12	12	12	12	12
Korea, Republic of	1,257	1,306	879	900	900
Latvia[e]	50	50	50	50	50
Lithuania[e]	30	30	30	30	30
Malaysia	473	509	447 [r]	575 [r]	580
Mexico	1,733	1,701	1,803	1,720	1,700
Netherlands[e]	5	3	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand[e]	25 [e]	41 [r]	47 [r]	48 [r, e]	45
Norway	1,000	1,314	1,300 [e]	1,500 [e]	1,400
Pakistan[e]	122	130 [e]	162	165 [r, e]	165
Paraguay[e]	10	10	25 [r]	28 [r]	25
Peru	96	90	74	74 [e]	74
Philippines	16	64	70	70 [e]	70
Poland	1,375	1,418	1,675 [r]	1,564 [r]	1,500
Portugal[e]	5	5	5	5	5
Serbia and Montenegro[e]	200 [4]	100	100	75	75
Slovenia[e]	200	200	200	200	200
South Africa	2,223	2,170	2,138	2,132	2,262 [4]
Spain[e]	6,200	6,550	6,600	6,500	6,500
Sweden[e]	500	500	500	600	600
Thailand	324	532	472	514 [r]	520
Turkey	1,138	1,211	1,485	1,400 [e]	1,400
United Kingdom[e]	4,662 [4]	4,600	4,500	4,500	4,500
United States, sold or used by producers	28,200	28,900	28,400	27,900	27,300 [4]

See footnotes at end of table.

TABLE 12--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	1998	1999	2000	2001	2002[e]
Venezuela	344	295	422 [r]	627 [r]	630
Zimbabwe[e, 8]	40 [r, 4]	40 [r]	121 [r]	28 [r]	7
Total	93,900 [r]	95,700 [r]	96,000 [r]	96,400 [r]	94,900

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. -- Zero.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through June 25, 2003.
[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, countries of the Commonwealth of Independent States (CIS), Iraq, and Saudi Arabia, produce industrial sand, but current available information is inadequate to formulate reliable estimates of output levels.
[4]Reported figure.
[5]Fiscal years beginning July 1 of that stated.
[6]The quantities for quartz sand and silica stone, in cubic meters, were as follows: 1999--140,428; and 2000-2002--145,000 (estimated).
[7]Fiscal years beginning March 21 of that stated.
[8]Includes rough and ground quartz as well as silica sand.

FIGURE 1
PRODUCTION OF CONSTRUCTION SAND AND GRVEL IN THE UNITED STATES IN 2002, BY GEOGRAPHIC DIVISION